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PRODUCTIVITY DISPERSION AND SOURCES OF TECHNICAL INEFFICIENCY IN SMALLHOLDER TIMBER MILLS IN OGUN STATE, NIGERIA

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ABSTRACT

The concept of technical efficiency is critical to measuring the firm performance, determining the degree of innovative technology adoption, overall production efficiency and sustainability of livelihood options. Our research evaluates technical efficiencies in the sawmilling sector. Specifically, the main objective of the study was to assess technical efficiency dispersion and determine the significant, firm-specific, factors that cause technical inefficiencies in sawmilling operations. Maximum-likelihood methods are applied in the estimation of the parameters of the model. In the study, panel (3 years) data from 68 sawmills was used in the empirical analysis. The primary decision-maker in the sawmill has an average age of 53years with a mean of 17years of experience in sawmill management. The average operational age of the sawmill is 13years. There were considerable wide variations, at the firm level, in technical efficiencies recorded over the periods. The estimated average technical efficiency of the sampled sawmills for the three years (2007-2009) is 61.9%. The result revealed that the initial efficiency gained in 2007 was not sustained as efficiency dropped in 2009 to 57.9%. The firm specific variables that influence technical efficiencies are owner's status as timber contractor, ownership of timber trucks, years of experience and age of the manager. The study recommends that technical and management training/workshop should be organized by relevant government agencies to regularly update operators' knowledge. Import policies should be targeted to encourage acquisition and use of modern sawmilling machines and equipment. Also, public power supply to the sawmill clusters should be improved to reduce the high processing cost associated with the use of diesel powered electricity generation sets.

Key words: Technical Efficiency, Forest, Timber, Sawmills

INTRODUCTION

Sustainable Forest Management (SFM) requires the balancing of economic, environmental, and social objectives in forest products and services exploitation. The linkage between SFM and timber economics lies in the desire to achieve a sustainable flow of economic goods (timber) from forests and to maintain healthy forests capable of providing benefits into the future (Bowles et al 1998; Barham *et al.,* 1999 and Wunder 2001). Timber is by far the highest-valued forest product in most forests. In 2008, the export of industrial roundwood, sawnwood and wood-based panels from developing countries accounted for US$13.1 billion (FAOSTAT, 2010). Under SFM, timber production requires economic efficiency in selecting inputs to produce the most valuable output. The concept of technical efficiency has been used in measuring the performance of a firm, determining the degree of innovative technology adoption as well as the overall production efficiency.

Nigeria has a total forest area of 13,517 ha which represents about 15% of the total land area. Of this, less than 12% is protected and the estimated rate of loss is 2.3% per annum (http://www.fao.org/countryprofiles/index.asp?subj=5&iso3=NGA). This portends a great challenge to conservation efforts and the sustainable exploitation of the asset. The inextricable nexus that exit between forest and sustainable livelihood in coping with poverty and food insecurity has been extensively researched; stressing both the direct and indirect benefits (Wallace and Newman, 1986; Vincent 1995; FAO 2001; Iversen *et al.,* 2006; Nelson 2006). Most of the studies on SFM have focused on the forest (upstream) level measures (planting, stand management and field harvesting), the importance of efficiency of utilization of products and products processing (downstream) has not been adequately addressed (Deacon, 1994; Iversen *et al.,* 2006; Barham *et al.,* 1999; Gerwin *et al.,* 1996; Place and Otsuka 1998; Wunder 2001; Bowles *et al.,* 1998). Against the backdrop of recent evidences that has linked products processing to sustainable forest use, it is therefore imperative to quantitatively analyze the efficiency of timber processing. As highlighted above, timber is the most economically important product of the forest. The saw mill is therefore, a critical industry whose performance not only has dire implications for present livelihood but also for the future generation. The study therefore, attempts to bridge the gap in knowledge by assessing the efficiency dispersion and causes of technical inefficiencies in sawmilling in Nigeria. Forest industry (sawmill) has the potential to improve economic performance and increase state and household revenues. The realization of these opportunities, however, depends critically on the efficiency of utilization and exploitation of products.

Specifically, the study objectives are to:

- determine the efficiency distribution of the sawmills in the state and,
- determine the firm's specific factors that limits technical efficiency in the industry

The study Area and timber harvesting regulations

The study was carried out in Ogun State, Nigeria. A Forest resource, especially timber, is the most important economic product. The state is home to some of Nigeria's largest forest reserves (J4, Omo and Olokomeji). It is referred to as the Gateway State due to its strategic location to Lagos State, the economic hub of the country. The estimated human population is 3.73 million, occupying a land area of 16,400 squared kilometers (NBS, 2008). It is largely agrarian in nature with a large rural population who depend on subsistence agriculture and forests resources as major source of livelihood.

There were about 350 registered sawmills in the state in 2008 operating mainly as smallholder, family industry (Ogun State Ministry of Forestry, 2009). The forest compartment for timber harvesting is allotted to registered timber contractors by the State Government. The Ogun Property Hammer (OGPH) identification seal represents the official permit to harvest timber from the State's forest. The property hammer cost N150,000 and N250,000 for individual and corporate permits respectively. The timber contractors pay a deposit of N250,000 as the prepaid cost of timber harvest from 10ha of forest land for a duration of 3 months. Forest-guards monitor the quality and quantity of timber harvested by individual contractors. There are other checks and gauges involving a combination of personnel and activities of Ranger and occasional spot checks on sawmills, put in place by the Ministry of Forestry to discourage sharp practices of illegal felling, over harvesting (including felling of under-girth trees) and encroachments. Penalties for illegal logging includes outright confiscation of vehicle and equipment, lockup of mills and subsequent payment of a fine of N100,000. Most sawmills are strategically located, in clusters, at the periphery of urban settlements. To operate in the state, sawmills are registered with the Ministry of Forestry. A preliminary payment of N150,000 for installation certificate is made followed by a yearly renewal fee of N20,000. Toll milling is the most common timber processing operations as most of the timber contractors do not own sawmills. Sawmilling activities is highly erratic; depending, mainly, on season, location of mill and general business condition.

The Technical Efficiency Model

Productivity has been studied by economists and policy makers for a long time. This is because in the long run, only productivity growth is considered as an engine for economic growth. Technical efficiency is just one component of overall economic efficiency. However, in order to be economically efficient, a firm must first be technically efficient. Profit maximization requires a firm to produce the maximum output given the level of inputs employed (i.e. be technically efficient), use the right mix of inputs in the light of the relative price of each input (*i.e.*, be input allocative efficient) and produce the right mix of outputs given the set of prices (i.e. be output allocative efficient) (Kumbhaker and Lovell, 2000). Technological change and efficiency improvement are important sources of productivity growth in any economy.

The concept of technical efficiency is based on input and output relationships. Technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible. Allocative inefficiency arises, when the input mix is not consistent with cost minimization criteria (Coelli, 1996; Wang and Schmidt 2002). In the case of sawmills, allocative inefficiency occurs when millers do not equalize marginal returns with true factor prices. Relative productive efficiency of firms within an industry is continually shocked by economic events as well as the process of adopting technical innovations. The diffusion of new and more efficient methods is, often, a slow, drawn-out affair (Place and Otsuka, 1998). The analysis of technical efficiency involves the assessment of the degree to which production technologies are being utilized.

Traditionally, technical efficiency has been measured as the ratio of observed output to maximum feasible output. Stochastic frontier models have been widely used to assess this issue (Wang and Schmidt, 2002; Alvarez and Crespi, 2003 and Alene *et al.,* 2006). In analyzing producers' technical inefficiencies, there is a need to carefully integrate the stochastic component of production into the stochastic frontier models in order to derive reliable information on input allocation decisions. Holmes *et al.* (2000) observed that, the common stochastic specification used in the economic literatures to estimate production functions can be too restrictive. This is because; traditional approximations do not allow the effects of inputs on the deterministic component of production to differ from their effects on the stochastic element of output (Battese and Coelli, 1995; Karagiannis and Tzouvelekas, 2003; Wallace and Newman, 1986). Since inputs can either increase or decrease output variability, the use of the stochastic frontier specification of input–output response has been introduced to correctly capture this effect. The stochastic frontier specification incorporates models for the estimation of technical inefficiency effects and simultaneously estimate all the parameters involved (Alene *et al.*, 2006; Kumbhakar, 2002; Bauer, 1990). This is the methodology adopted in this study. The technique assumes that, for a given combination of inputs, the maximum attainable production by a firm is delimited from above by a parametric function of known inputs involving unknown parameters and a measurement error. The more distant actual production is from this stochastic frontier, the greater a firm's technical inefficiency. Also, the stochastic estimations incorporate a measure of random error; this involves the estimation of a stochastic production frontier, where the output of a firm is a function of a set of inputs, inefficiency and random error.

The assumption that technical efficiency is constant through time is very strong in operating environments that are competitive. However, in a developing market economy there is the need to relax this rule as technical efficiency cannot remain constant over time. Also, considering the fact that the industry is in a state of flux; and no individual firm can be said to be operating at a technically optimal level. Stochastic frontier models utilizing panel data enable researchers to estimate individual firms' technical or allocative inefficiencies without imposing arbitrary distributional assumptions on them (Wang and Schmidt 2002). One weakness of this approach is that firms' inefficiencies are time-invariant. Recent studies have proposed alternative models that allow firms' inefficiencies to change over time in some restrictive forms. Panel data model with multiple time-varying individual effects forms the foundation of our frontier model; we assume that firms' inefficiencies consist of multiple components each of which changes over time in a temporal pattern common to all individual firms. One advantage of the time variant model is that technical inefficiency changes over time can be distinguished from technical change. The mathematical evaluation of the sigma (*s*) and gamma (*g*) are indicated below:

$$s^2=s_V^2+s_U^2\ ;\ g=s_U^2/(s_V^2+s_U^2)$$

The distributional assumptions of stochastic frontier analysis for a time variant firm are half normal distribution, truncated normal distribution and a one step inefficiency model. A time variant panel data production frontier model allows technical efficiency to vary across industries and through time for each firm.

The time-varying stochastic frontier production model is given as:

$$y_{it} = \delta_t + x'_{it} + \varepsilon_{it} - \mu_{it} \equiv x'_{it}\beta + \eta_{it} + \varepsilon_{it}$$

where *i* indexes sawmill units, and t indexes time periods (3 years). The dependent variable is y_{it} represents the logarithm of the output of the sawmill *i* at time *t*, x_{it} is the kx1 vector of logarithms of inputs, b is a kx1 vector of coefficients, and ε_{it} is the random noise (that are assumed to be iid $N(0, \sigma_V^2)$) which represents the stochastic component of the frontier. The time-varying parameter δ_t is the frontier intercept term at time t.

Empirical framework

To assess the dispersion of technical efficiency in the mills the study relied on panel data of firm-level micro-data from 68 randomly selected sawmills in Ogun State. The 68 firms represent 50 percent of the population of sawmills that were actively engaged in timber processing within the 3 years period (2007-2009). The use of a panel of data in efficiency estimation offers advantages over a cross sectional data analysis since it allows technical efficiencies to vary due to individual differences and the passage of time (Binam *et al.,* 2004; Chavas *et.al.,* 2005; Haji, 2006). Data on volume and value of timber received and processed into logs, labour, fuel and utilities expenses and capacities of mill were collected and analyzed.

The stochastic production frontier model (Cobb-Douglas) fitted for the analysis of technical efficiency in the production of logs/boards (m^3/month) is:

$lny_{it} = \beta ln\, x_{it} + (V_{it} - U_{it})$; i=1...n; T=1…3 and t=1...36

where, lny_{it} is the logarithm of the total sawn log produced per month by the ith sawmill. The vector lnX_{it} is the log value of inputs, x_i, (technical determinants) which are:

X_1= volume of softwood timber processed (m^3/month)

X_2= volume of hardwood timber processed (m^3/month)

X_3 = skilled labour use (workdays/month)

X_4 = machine input

X_5 = utilities and diesel use (naira/month)

X_6 = Time (years)

The inefficiency (U_{it}) term include a constant. There are 6 inefficiency term regressors, the choice of which is hinged on the peculiarity of the industry's structure and operations. The factors include (U_1), a dummy variable that takes the value of 1 if the sawmill owner is a timber contractor and zero otherwise (U_2), a dummy variable that takes the value of 1 if the sawmill is located in rural location and zero otherwise (U_3), a dummy variable that takes the value of 1 if the sawmill has timber truck (*agbegi)* and zero otherwise (U_4), the age of the sawmill owner/manager (primary decision-maker) (U_5), years of experience of the owner/ manager in timber processing, and operational age of mill (U6). The variables operational age of the mill and age of the manager were expected to reduce efficiency. In terms of years of experience, since the manager is likely to learn from previous errors, the passage of time should be expected to improve technical efficiency. Also, younger owners/ managers are expected to be more open to adopt changes in sawmilling management techniques that will reduce inefficiency, relative to the elderly ones. Timbers contractors (U_1) are authorized loggers; with official permit to harvest mature timber from the forest. It was expected that technical efficiency will enhance from a forward vertical integration in operating sawmill. Location (U2) advantage for a firm is imposed either from proximity to buyers and the source of raw materials or proximity to technical knowledge. Mills are dispersed in rural areas and located in clusters in urban areas. It is expected that technical efficiency will be enhanced in urban mills due to the ability of operators to learn efficient processing skills from contiguous mill. Also, ownership (U3) of timber trucks (*agbegi)* is expected to positively influence technical efficiency.

The Cobb-Douglas was fitted as oppose to other non-linear function such as the translog production function. The translog function, though a more flexible functional form than the Cobb-Douglas function as it takes account of interactions between variables and allows for nonlinearity in the parameters, has been found to frequently yield implausible estimates. Gumbau-Albert and Maudos (2002) reported that translog-type of production function often yield implausible estimates (e.g, negative elasticities of production for certain inputs or sum of scale elasticities much larger than one). Also, in translog production function multicollinearity among the explanatory variables is usually present.

The technical efficiency estimate obtained for the three years studied were subjected to the Kruskal-Wallis approach for Chi-square estimation, to ascertain significant differences. This was done to further establish significant time-varying effect on sawmills' technical efficiency.

RESULTS

The mill characteristics based on age revealed that majority of the mills have been actively involved in timber processing. About 57% of the mills were established between 11-20 years ago. The mean operational age of sawmills in the area is 13.4years which indicate that sawmilling industry has long years of establishment in the State. Toll milling or contract timber sawing is a common practice in the area. In toll milling, timbers are processed into logs by contractors or other parties (end users, marketers, middlemen) for a fee. The fee charged varies with mill location, type of log, season, cut specifications and quality as well as power source used (different charges for use of diesel powered generator and electricity supply from the public power company).

Majority (about 53%) of the millers were found to be within the age range of 51-60 years with an average age of 53.4 years. The distribution based on years of experience in timber milling revealed that majority (about 60%) of the operators have over 10 years of experience in sawmilling, with mean of 19.4 years. The mean number of years in formal education was about 9 years.

The Stochastic Frontier analysis revealed that the first-order parameters, Xk, are all positive and statistically significant thus indicating that production is increasing with increases in the inputs considered. The estimated sigma-squared (σ^2) shows the overall significance of the model, it indicates a good fit and correctness of distributional assumption specified. The gamma (γ) measures the effect of technical inefficiency in the variations observed in output. It shows that, the difference between the observed and maximum production frontier outputs are due to differences in farmer's level of technical efficiency and not related to random variability. It suggests the relevance of technical inefficiencies in explaining output variations over the period. It also suggests that one should not rely solely on the average production function (technical relationship between inputs and outputs) response as an adequate representation of the sample data. The inputs that influence the output of logs and boards are volume of timber (hard and soft wood), numbers of skilled sawmill labour used, sawmill machines and equipment used and utilities. The positive signs show that output responds positively to relative increase in these variables. The positive sign of the technical change coefficient (time) indicates that the value of output increased over the three year period.

The estimated U_i coefficients help us to understand the determinants of technical efficiencies. The significance of the sigma statistic shows that there are relative firm-level

Table 1: Sample Characteristics of the Sawmills and Primary Decision Maker

Characteristics of the mill	Frequency	Percentages	Mean
Age of mill			
< 5 years	2	2.94	18.4years
5-10years	12	17.64	
11-20 years	39	57.35	
>20 years	15	22.07	
Involved in toll milling activities			
Yes	63	92.64	
No	5	7.36	
Characteristics of primary decision maker			
Age			
< 40 years	7	10.29	53.4years
41-50 years	18	26.48	
51-60 years	36	52.94	
>60 years	7	10.29	
Highest educational qualification			
No formal education	6	8.82	9 years
Primary education only	41	60.32	
Secondary education	16	23.52	
Post secondary education	5	7.34	
Years of experience in sawmilling			
< 5 years	5	7.34	17 years
5-10years	23	33.82	
>10 years	40	58.84	
Is owner a timber contractor			
Yes	9	23.24	
No	59	86.76	
Own other functional sawmills			
Yes	4	5.89	
No	64	94.11	
Ownership of functional timber trucks			
Yes	46	67.65	
No	22	32.35	

Source: Field survey (2009)

and longitudinal inefficiencies in sawmilling operations in the State. Years of experience in timber milling, ownership of timber trucks, status of the mill owner as a timber contractor, and operational age of the mill were found to be major sources of inefficiency in the industry. The age of the mill, age of owner/manager, ownership of timber trucks (*agbegi*) and status as contractor had significant negative effect on technical efficiency. However, experience in milling operations had a significant positive effect on technical efficiency.

Table 2: Maximum Likelihood Estimates of the Production Frontier Model for sawmills in Nigeria, 2007-2009

Regressors	Identifiers	Estimates	t- statistics
Production frontier			
Softwood timber processed (m3/month)	X1	0.534**	7.061
Hardwood timber processed (m3/month)	X2	0.1032**	7.003
skilled labour use (workdays/month)	X3	0.3791*	2.630
Machine input	X4	0.1162*	2.191
utilities and diesel use (naira/month)	X5	0.4021**	4.033
Time	X6	0.192*	3.096
Constant	X0	0.551**	4.933
Technical efficiency			
Timber contractor	U1	-0.211*	-2.991
Location of sawmill	U2	2.871	1.092
Ownership of timber trucks	U3	-0.071*	-3.231
Age of primary decision maker	U4	-0.025*	-3.083
Experience of primary decision maker	U5	0.652**	3.920
Operational age of mill	U6	-0.003*	2.229
Constant	U0	-1.281**	4.670
Eta		0.745	5.221
Sigma-squared	$\sigma 2$	3.334	3.980
Gamma	γ	0.9403	4.774
Log likelihood function =	-821.22		

Source: Data Analysis (2009)
** Parameter significant at 1percent probability level
* Parameter significant at 5 percent probability level

Table 3: Mean technical efficiency distribution in the sawmills by year

Range of technical efficiency (%)	2006	2007	2008	Total
< 30	13	8	6	27
30-40	4	0	3	7
41- 50	10	12	11	33
51-60	15	24	15	54
61-70	17	6	10	33
71-80	3	5	8	16
81-90	5	9	7	21
>90	1	4	8	13
Mean	**61.76%**	**66.02%**	**57.92%**	**61.90%**

Source: Data Analysis (2009)

The mean technical efficiency estimated was found to be 61.9% during the period studied

Specifically, technical efficiency increased from 61.76% in 2007 to 66.02% in 2008 and then fell to 57.92% in 2009. The efficiency gains recorded in 2007 and 2008 were not sustained, as relative inefficiency increased in 2008 to about 42%. Economic and social conditions such as fall in demand for logs and boards, high transportation and processing costs (predominantly high cost of diesel) and increase in illegal logging activities were reported as some of the factors that had adverse effect on sustainable timber milling during the period. The technical efficiency estimates of the mills in the three years studied were further subjected to test of significance difference to ascertain relative difference in the values obtained. The result shows that the values obtained were significantly (X^2=5.25; p $\leq$ 0.05) different over the period.

Table 4: Test of significant differences in time-varying technical efficiencies of sawmills

		Technical efficiency (%)			Kruskal wallis test
year	min	max	Standard dev.	mean	X2
2006	18.7	93.8	23.6	61.7	
2007	22.1	98.3	21.4	66.0	5.251*
2008	13.7	94.6	17.6	57.9	

Source: Data Analysis (2009)
*significant at 5 percent probability level

CONCLUSION

There is a high productivity dispersion across firms in the sawmill industry. The technical efficiency measures over the periods also reveal temporal differences in the productivity of the firms. The average technical efficiency for the three years (2007-2009) was 61.9%. Firm level sources of inefficiency associated with firm characteristics/features as well as management activities are implicated. The problems of high processing costs (mainly from high energy costs), variability in inputs and log prices and lack of requisites technical capacities to manage mill equipment and machineries were found to be constraints to profitable timber mill operations in the area. The study recommends that practical workshops/training and retraining should be organized to update capacities of operators on routine mill machineries management and cost effective milling. Public power supply to sawmill industrial clusters should be improved to reduce the processing overheads. Also, the relevant public agencies need to enforce regulations and monitoring, and, should develop standards and grades for different timber and wood products.

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